Project Report: Virus surveillance in peppers, including specific monitoring of spotted wilt and curly top in hot-spots and completion of a jalapeno pepper line with resistance-breaking (RB) tomato spotted wilt virus (TSWV)

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Overall objective:

To (i) provide an effective statewide surveillance system for virus (and other) diseases of peppers in California, (ii) specifically monitor and research exotic and newly emerged viruses as well as unusual outbreaks of known viruses, and (iii) provide outreach in the form of field visits, grower talks, and detailed reports

Specific Objectives for 2025:

1. Effective surveillance of peppers in California for viral diseases and specific monitoring of spotted wilt and thrips and curly top and beet leafhoppers in areas with recent outbreaks

2. Continued characterization of pepper RB isolates from our surveillance network and monitored fields to understand the evolution of RB isolates

3. Screening of jalapeno breeding lines for resistance to pepper RB TSWV

1. Effective surveillance of peppers in California for viral diseases and specific monitoring of spotted wilt and thrips and curly top and beet leafhoppers in areas with recent outbreaks

For this objective, we continued to receive samples of pepper plants with virus-like symptoms from our network of (i) Farm Advisors; (ii) growers and PCAs; (iii) Matt Terra and his team as they visit fields and trials statewide; and (vi) our own field visits and surveys. **In 2025, we were fortunate to add Dr. Ana Maria Pastrana, Farm Advisor for Imperial and San Diego counties to the surveillance team.**

In 2025, we conducted **intensive monitoring** of pepper fields for viral diseases in Yolo County in collaboration with Jordan Fricke of Muller Ag. Here, we are targetting thrips and tomato spotted wilt disease (TSWD). The Yolo County monitoring was led by Dr. Tomas Melgarejo and Farm Advisor Patricia Lazicki. For the surveys in Ventura, we again worked with Max Babylon of Bayer and his team to conduct yellow sticky card (YSC) monitoring and surveys of pepper fields in Ventura for symptoms of curly top disease (CTD). **Thus, we believes this network provides a high probability of recognizing outbreaks of virus-like diseases in pepper fields in California.**

In Table 1, the overall results of tests performed on pepper samples with virus-like symptoms collected or received in 2025 are presented according to county from which samples were received and results of virus tests on these samples. The overall incidence of virus disease in pepper fields in California was low in 2025.

The greatest number of samples was from Yolo County (126) and Ventura (26), reflecting our more intensive sampling in these locations. **The most widely detected viral disease was TSWD,** which was detected in samples from three counties. The incidence of CTD of pepper in 2025 was very low, including in Ventura (see below).

Peppers with typical CTD symptoms were received from San Joaquin County and these tested positive for infection with the mild-type BCTV strain, BCTV-CO, which typically infects peppers in California.

We did detect a **higher incidence and more diversity in aphid-transmitted viruses in Yolo County in 2025.** This included alfalfa mosaic virus (AMV), cucumber mosaic virus (CMV) and the potyviruses pepper mottle virus (PepMoV), tobacco etch virus (TEV) and potato virus Y (PVY) (Table 1).

Table 1. Number of pepper samples collected or received in 2025, and results of virus tests conducted on these samples

County	Total	TSWV	AMV	Poty	CMV	BCTV	TMV	PMMoV	Other*
Yolo	126	92(+)	15(+)	12(+)	6(-)	1(-)	6(-)	NT	0
San Joaquin	16	11(-)	NT	5(-)	5(-)	5(+)	NT	NT	0
Ventura	26	7(-)	NT	7(-)	4(-)	13(-)	4(-)	7(-)	6
San Diego	1	1(+)	NT	NT	NT	NT	NT	NT	0
San Benito	11	6(+)	5(-)	5(-)	5(-)	NT	NT	NT	0
Yuma	2	2(-)	NT	NT	NT	NT	NT	NT	2
Total	**182**	**99(+) 20(-)**	**15(+) 5(-)**	**12(+) 9(-)**	**0(+) 20(-)**	**5(+) 14(-)**	**0(+) 10(-)**	**0(+) 7(-)**	**8**

*Samples showing symptoms associated to abiotic agents

Intensive monitoring in pepper fields in Yolo County. In 2025, we monitored thrips populations with YSCs and TSWD incidence based of field surveys at 4 pepper fields: Meek-6, Mezger, Muller and Syar North from early April to July 2025. The results are shown in Figure 1. Thrips populations gradually increase and peaked in late May and early June followed by decreasing populations in July. The highest thrips populations were at Syar North where as many as ~2200 thrips were capured on some YSCs at this location in late May and ~1000 in early July (Figure 1).

Notably, the **Syar North pepper field also had the highest incidence of TSWD, ~12%, by early July when harvest was underway** (Figure 1). The other fields had less thrips captured on YSCs, with Mezger the least <500/YSC and Muller and Meek-6 having 500-1000. Interestingly, these fields had substantailly lower TSWD incidence (~1-3%), and this level had declined by early July. **Overall, TSWD appeared later in the season, except Syar North, indicating pepper plants were being infected via thrips entering the fields rather than in TSWV-infected transplants.** Overall, **spread within fields was also slow**, possibly due to thrips management, i.e., spraying of insecticides.

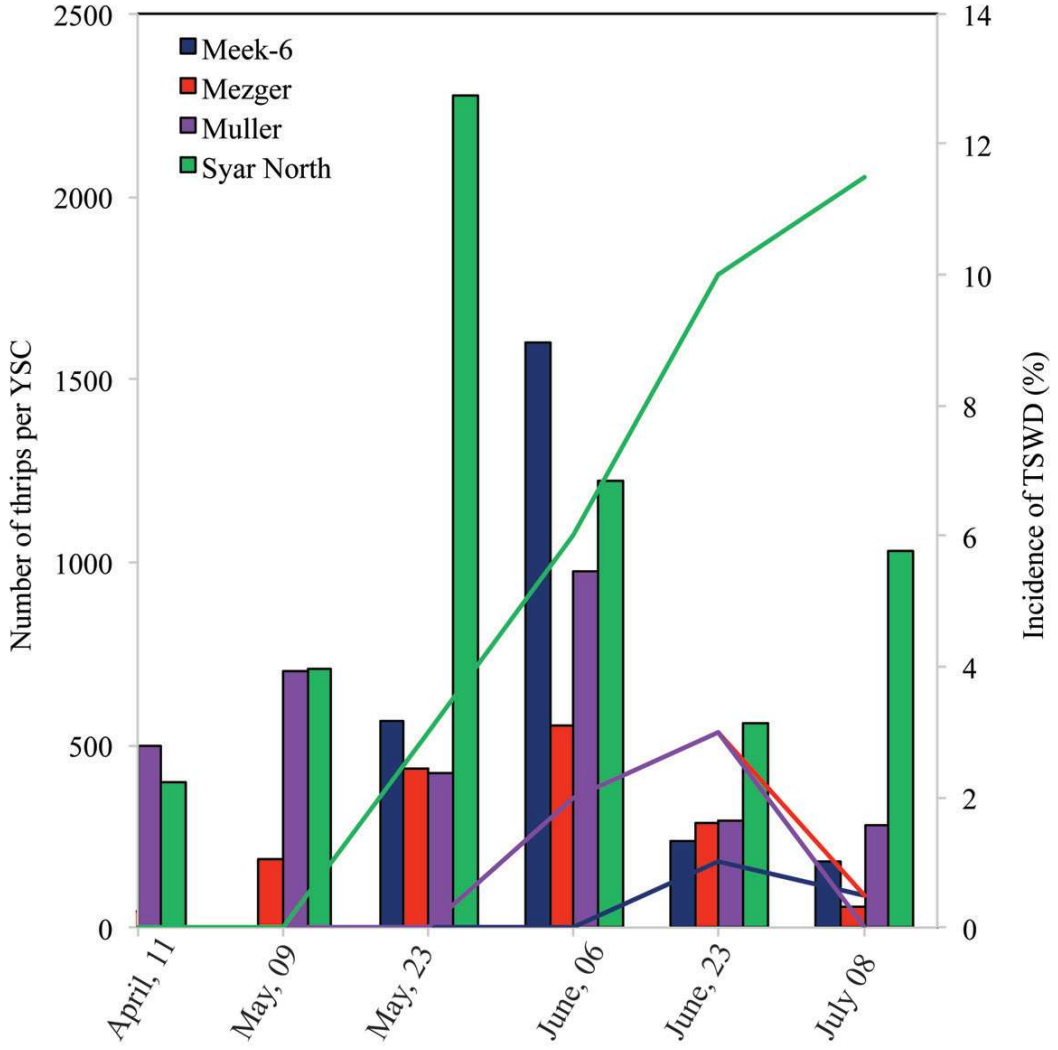

Figure 1. Results of monitoring pepper fields in Yolo County for thrips (with yellow sticky cards) and tomato spotted wilt disease (TSWD) incidence (based on symptoms) from early April to early July. Bars represent thrips numbers and lines show incidence of TSWD.

We next determined what were the predominant thrips species being captured on YSCs placed around pepper fields. It had been previously determined that, at least in Yolo County, two species of thrips are captured on YSCs: *Frankliniella occidentalis*, the western flower thrips (WFT), and *Thrips tabaci*, the onion thrips. To differentiate these two thrips species, we used a previously developed multiplex PCR test. As shown in Table 2, ***F. occidentalis* was the predominant species captured on YSCs around all four pepper fields,** with small numbers of *T. tabaci* also captured on these YSCs (Table 2). Thus, high populations of the vector of TSWV were present around all four pepper fields monitored in Yolo County in 2025, although the amount of virus carried by these thrips was not determined.

Table 2. *Frankiniella occidentalis* was the predominant thrips species captured on yellow sticky cards (YSCs) around the four monitored pepper fields in Yolo County in 2025 along with small numbers of *Thrips tabaci*

Field	Total number of YSCs	Number of YSCs with *Frankliniella occidentalis*	Number of YSCs with *Thrips tabaci*
Meek-6	21	21	2
Mezger	24	24	4
Muller-12	24	24	2
Syar North	24	24	0
Total	**63**	**63**	**8**

Monitoring in Ventura Co. in 2025 reveals a different virus-like disease of peppers in 2025

The monitoring program in pepper fields in Ventura was initiated in response to outbreaks of curly top disease (CTD) in pepper fields in the Piru area in 2024. This program was initiated in 2025 in collaboration with Max Babylon and his team from Bayer and **involved YSC monitoring for beet leafhoppers (BLHs) and field surveys for CTD symptoms**.

In 2025, CTD symptoms were not observed in monitored pepper fields in Ventura, including in the Piru area where the disease was observed in 2024. However, we captured low populations of BLHs on YSCs around pepper fields in the Piru area (BLH numbers for June 12: 7. 10, 8; July 15: 0, 4, 52; and July 29: 7, 4, 0) with BCTV detected in BLHs from the YSCs of 7/29/25. Very few BLHs were detected on YSCs from around pepper fields at other locations, e.g., the Oxnard Plain. These results indicate the **BLHs and BCTV were in the Piru area in 2025 but did not reach the high populations of BCTV-carrying BLHs needed to result in substantial outbreaks of CTD.** We were not monitoring BLH in 2024, so we do not know what BLH populations were associated with the CTD outbreaks in pepper for that year.

In late August 2025, Max sent us pepper plants from the Oxnard Plain showing a very striking curling of leaves and interveinal yellowing (Figure 2). We initially thought this might be unusual CTD or phytoplasma symptoms but PCR tests of leaves of plants with these symptoms were negative for BCTV and phytoplasma infection. However, closer inspection of these plants revealed lots of psyllids, which suggested this could be psyllid yellows disease (PY). PY is associated with the phloem-limited non-culturable bacteria Candidatus *Liberibacter solanacearum* (Lso).

Figure 2. Psyllid yellows (PY) symptoms in a pepper plant from a field on the Oxnard Plain in 2025 and psyllids collected from this plant.

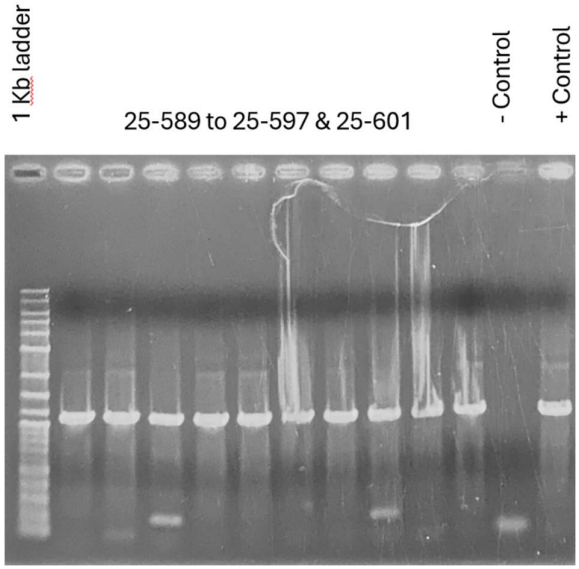

Figure 3. PCR detection of *Candidatus Liberibacter solanacearum* (Lso) in pepper plants with psyllid yellows (PY) from the Oxnard Plain.

Therefore, we performed a PCR test for Lso and the expected size ~1.1 kb DNA fragment was amplified from all samples with the PY symptoms and not from a healthy pepper plant (Figure 3). Sequences of this fragment from selected samples were determined and comparisons with known Lso sequences revealed ~99% identity, thereby

confirming infection of these pepper plants with Lso. Notably, the YSCs from 8/28/25 revealed high numbers of psyllids on the YSCs from the Oxnard Plain locations and much lower numbers on cards from other locations, including Piru (Table 3). PCR tests of psyllids from the original pepper samples and some from YSCs from the Oxnard Plain revealed the presence of Lso (Table 3). We also identified the psyllid species by sequencing the cytochrome oxidase I (COI) gene and detected two species, including the known vector, the potato psyllid (*Bactericera cockerelli*).

Moreover, the confirmation of PY of peppers on the Oxnard Plain in 2025 suggests the unknown virus-like disease observed affecting peppers growing on the Oxnard Plain in 2023 may have been PY. Thus, there can be **two virus-like diseases affecting peppers in Ventura** and that may be **associated with different parts of the county:** BLH and CTD in the Piru area and PY and psyllids on the Oxnard Plain.

Table 3. Numbers of Psyllids Captured on YSCs

Date	***YSC***	***Station***	***Psyllids***	***Lso***
06/02/25	38	1	0	-
06/02/25	39	2	0	-
06/02/25	40	3	1	-
06/02/25	41	5	9	+
06/02/25	42	6	21	-
06/02/25	43	9	0	-
06/02/25	44	10	8	-
06/02/25	45	11	8	-
06/02/25	46	12	15	-
08/28/25	137	11	550	-
08/28/25	138	12	300	+
08/28/25	139	13	125	+
08/28/25	140	14	43**	+

**half of the YSC was covered with soil

2. Continued characterization of pepper RB isolates from our surveillance network and monitored fields to understand the evolution of RB isolates

The **worldwide emergence of TSWV RB strains** reflects the capacity of this RNA virus to generate mutants, some of which overcome resistance conferred by the *Tsw* gene in pepper and the *Sw-5b* gene in tomato (Table 4).

Table 4. Major resistance-breaking (RB) tomato spotted wilt strains detected in California and their infection of differential species/varieties

	Pepper	**Pepper**	**Tomato**	**Tomato**	**Tobacco**
TSWV strain	**Susceptible**	**Resistant *Tsw* gene**	**Susceptible**	**Resistant *Sw-5* gene**	***N. benthamiana***
Wild-type	+	-	+	-	+
RB pepper	+	+	+	-	+
RB tomato	+	-	+	+	+
Super RB	+	+	+	+	+

In California, **RB TSWV appeared in tomato in 2016**, about five years after widespread deployment of the *Sw-5b* gene in fresh market and processing tomato varieties. This tomato RB strain (YPT) infects pepper but does not break the *Tsw* gene in pepper. **RB TSWV in pepper was first detected in 2017 in Yolo County**, and this strain infects tomato but does not break the *Sw-5b* gene. However, beginning in 2019 we began detecting RB TSWV strains that broke the resistance of the *Sw-5b* gene in tomato and the *Tsw* gene in pepper, which we refer to as the **super RB strains (SRB) (Table 4). In Yolo County SRB strains have been encountered with increasing frequently in pepper and tomato.**

In 2025, we continued characterizing isolates of TSWV from pepper to understand **what the population dynamics of RB strains were in various locations**. A total of 99 pepper samples with TSWD symptoms were collected or received in 2025. As shown in Table 5, most of these were from Yolo County (92/99), and most were collected from susceptible pepper varieties. Of the 92 samples from Yolo County, 37% were tomato RB YPT strain, 33% were tomato RB CPN strain, 7% had mixed infection of CPN+YPT and 24% were not infected with either tomato RB TSWV strain and could be WT or the RB pepper strain (Table 5).

Recall that **to identify TSWV RB pepper strains it is necessary to mechanically inoculate pepper seedlings of a resistant variety**, in our case cv. Huntington, and look for systemic infection. To date, we have evaluated 15 isolates by mechanically inoculating susceptible and resistant pepper seedlings, and **13 (87%) of these were RB pepper isolates** (Table 5). So far, these results indicate ~2/3 of isolates from pepper in 2025 in Yolo County were RB tomato and even more were RB pepper. **Thus, the vast majority of the TSWV isolates from pepper in Yolo County in 2025 are SRB, indicating a selective advantage and capacity to persist**. This also suggests that the *Sw-5b* gene in tomato and the *Tsw* gene in pepper will be less effective.

Table 5. Number of pepper samples with spotted wilt symptoms tested for tomato and pepper RB-TSWV strain(s) in 2025

		TSWV-RB Strains				Reaction in
County	**TSWV**	**CPN**	**YPT**	**Mix (CPN/YPT)**	**Negative (CPN/YPT)**	**pepper cv. Huntington**
Yolo	92(+)	30(+)	34(+)	6(+)	22	WT(2+) RB(13+)
San Diego	1(+)	0	1(+)	0	0	NT
San Benito	6(+)	0	3(+)	0	3	NT
Total	**99**	**30**	**38**	**6**	**25**	**15**

3. Screening of jalapeno breeding lines for resistance to pepper RB TSWV

This part of the project **involves our collaboration with Allen Van Deynze in breeding peppers with resistance to TSWV RB pepper strains.** We recently completed a screening of 580 pepper plants as part of this project. This was accomplished by mechanical inoculation of young plants (3-5 leaf stage) with an isolate of the TSWV pepper RB strain from Yolo County in a controlled-temperature greenhouse on the UC Davis campus. Controls included susceptible and resistant (cv. Huntington) cultivars. The trial was recently completed and the development of TSWD was as expected and plants of both contrals developed severe symptoms, albeit somewhat slower. The 580 inoculated plants were rated for TSWD severity and these results will be passed on to Allen's group.

Take home messages for 2025:

-Overall low incidence of virus disease in peppers in 2025

-Uptick in virus diseases caused by aphid-transmitted viruses in Yolo County

-TSWD continues to be most important, whereas very little CTD

-Outbreak of virus-like disease of peppers on Oxnard Plain shown to be PY, which is associated with the non-culturable phloem-limited bacterium Lso

-Molecular tests confirmed Lso infecting diseased pepper plants and in psyllids from these plants and YSCs

-Was PY is the virus-like disease of peppers observed on the Oxnard Plain in 2023?

-Extensive monitoring of TSWD and thrips in Yolo County in 2025 revealed delayed appearance of TSWD, association of thrips populations and TSWD incidences ranging from 3-12%.

-The majority of TSWV isolates from peppers in Yolo County in 2025 were the SRB strain

-*F. occidentalis* (WFT) was predominant thrips captured on YSCs around all four monitored pepper fields with a small number of *T. tabaci*

-We feel that this surveillance system is working effectively to allow for rapid detection, identification, and reporting of relevant information